DIRECT CARBONATE FUEL CELL FOR SHIP SERVICE APPLICATION

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INTRODUCTION

Compared to gas turbines and combustion engines, fuel cells possess the potential for much higher efficiency, near negligible emissions, quiet operation, and modularity. In 1997, the Office of Naval Research (ONR) initiated a three-phase advanced development program to evaluate fuel cell technology for ship service power requirements for surface combatants. The program is designed to demonstrate that commercially developed fuel cell technology can operate on Navy logistic fuel in a naval shipboard environment. As part of ONR's program, Energy Research Corporation (ERC) is conducting a conceptual study of a marine fuel cell power plant based on its direct carbonate fuel cell technology which is in the early commercialization phase for land-based applications. The current Phase I study is focused on a 2.5 MW Ship Service Fuel Cell (SSFC) power source for future surface combatants.

TECHNICAL APPROACH

ERC's technical approach is based on adapting the company's commercial Direct Fuel Cell (DFC™) technology for marine applications. This fuel cell system utilizes alkali metal carbonates as the electrolyte and operates within a stack temperature of 1100-1200°F where internal reformation of hydrocarbon fuels is feasible. Because the process waste heat is captured by the endothermic fuel reforming reaction, the DFC stack provides overall power plant efficiency of approximately 50%.

DFC technology is unique in that it can operate directly on hydrocarbon fuels following desulfurization and conversion to methane. The approach to processing of the NATO F-76 marine distillate fuel is based on hydro desulfurization followed by adiabatic prereforming to a methane-rich gas which can be reformed internally by the fuel cell.

2500 kW SSFC DESIGN

The baseline design concept for the 2500 kW SSFC is four independent 625 kW modules delivering power in parallel to the ship service 450 volt bus. Each 625 kW module has two stacks of direct carbonate fuel cells in series providing 450-600 volts dc to the power conditioning system which converts the DC to AC power. A simplified process schematic is shown in Figure 1 for this module. The fuel processing system desulfurizes the NATO F-76 and converts it to a methane-rich gas useable by the fuel cell. The required steam is generated using waste heat from the fuel cell cathode exhaust. The water required for steam generation is recovered from the fuel cell anode exhaust.

The equipment for each of the independent 625 kW power plant modules is contained within its own enclosure, which provides a closed environment for safety and attenuation of noise from the pumps and blowers in the system. Each 625 kW module contains two fuel cell stacks, power conditioning equipment, a fuel processor, thermal management and controls. The projected efficiency of the SSFC power plant over the range of power plant load is shown in Figure 2. The efficiency in a power plant that uses direct carbonate fuel cells is exceptionally high because all the energy required in the fuel conversion process is provided by the waste heat generated in the fuel cells. The efficiency of a commercial 2500 kW gas turbine generator set at ISO conditions is shown for comparison.

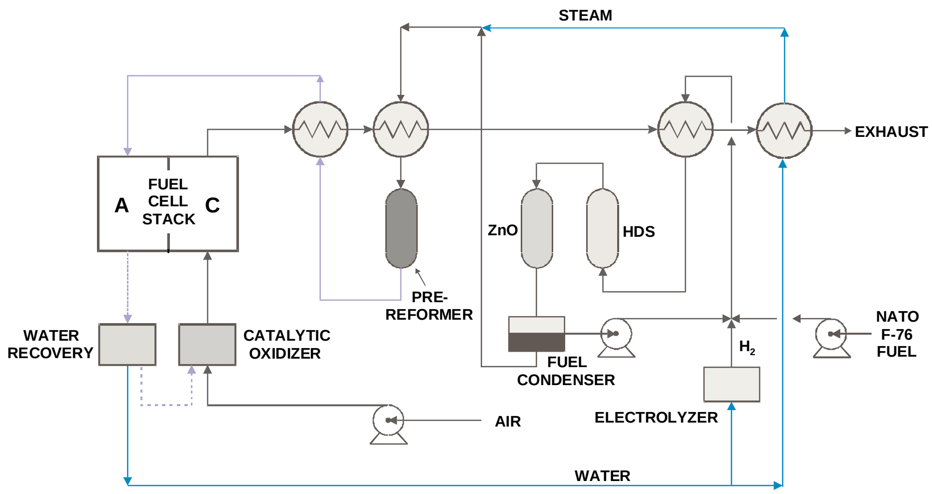

Figure 1. SSFC POWER PLANT PROCESS FLOW DIAGRAM (SIMPLIFIED)
Each Module is Fully Autonomous

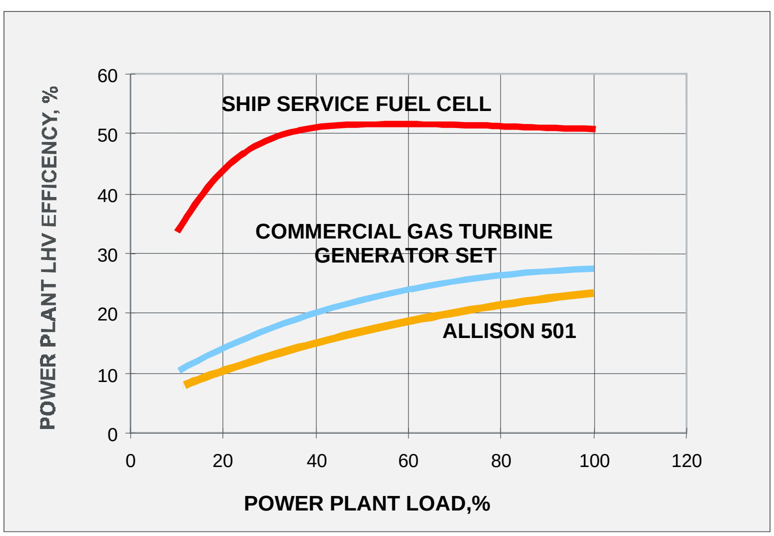

Figure 2. SSFC EFFICIENCY COMPARED TO A GAS TURBINE
SSFC Peak Efficiency Exceeds 50%

ACKNOWLEDGMENT

This work is sponsored by the Office of Naval Research. The technical effort is conducted under the direction of the Naval Surface Warfare Center's Carderock Division under Contract N00167-97-C-0080.

REFERENCES

Abens, S.G., and Kumm, W.H., "Evaluation of Reformation of Diesel Type Fuel in an MCFC Stack". Proceedings of the 35th International Power Sources Symposium, Cherry Hill, NJ. June, 1992.

Steinfeld, G., Skaanderup-Larsen, J., Kurpit. S.S., "Diesel Fuel Processing for Phosphoric Acid Fuel Cells". Proceedings of the 21st IECEC Conference, San Diego, CA, August 25-29, 1986.

Abens, S.G., Steinfeld, G., "Direct Carbonate Fuel Cell Power Plant Operating with Logistic Fuels". Proceedings of the 32nd IECEC Conference, Honolulu, HI, July 27-August 1, 1997.

Steinfeld, G., Sanderson, R., Ghezel-Ayagh, H. and Abens, S., "Concept Development of a Ship Service Fuel Cell", 1998 Fuel Cell Seminar Abstracts, Palm Springs, CA, November 16-19, 1998.